June 28, 1960 E. O. LAWRENCE ET AL 2,943,230

STORAGE-TYPE COLOR DISPLAY TUBE

Filed March 11, 1958 2 Sheets-Sheet 1

FIG-1

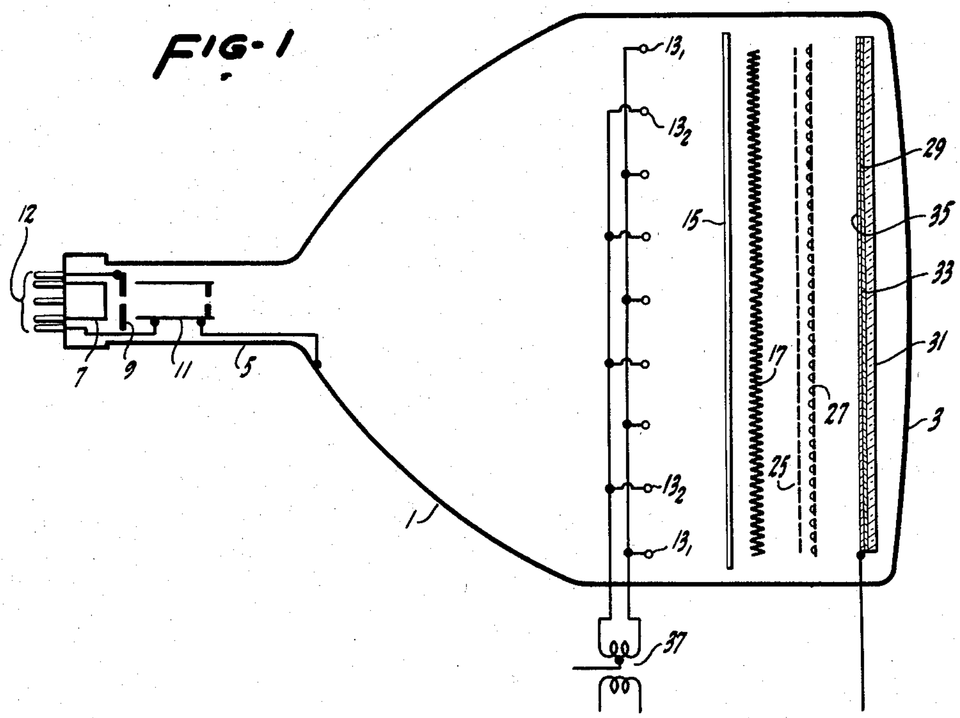
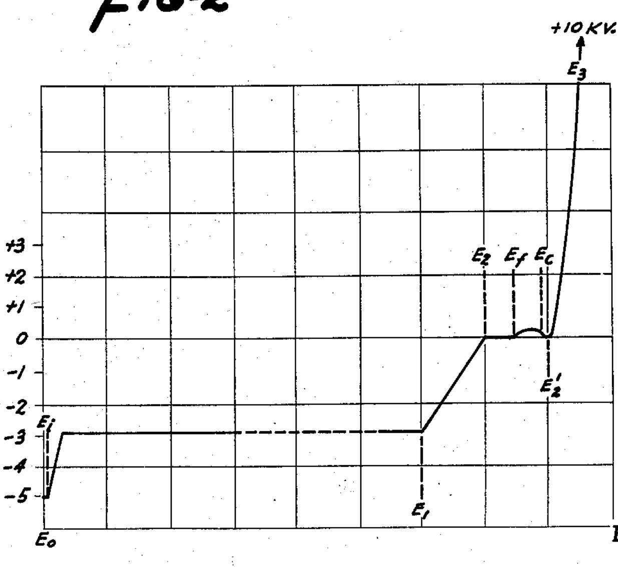


FIG-2



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STORAGE-TYPE COLOR DISPLAY TUBE

Filed March 11, 1958 2 Sheets-Sheet 2

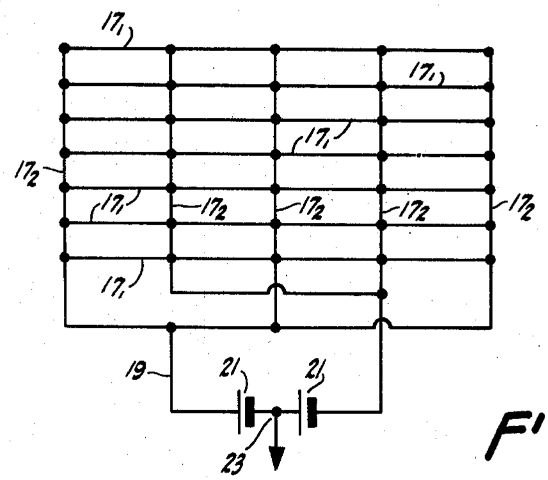
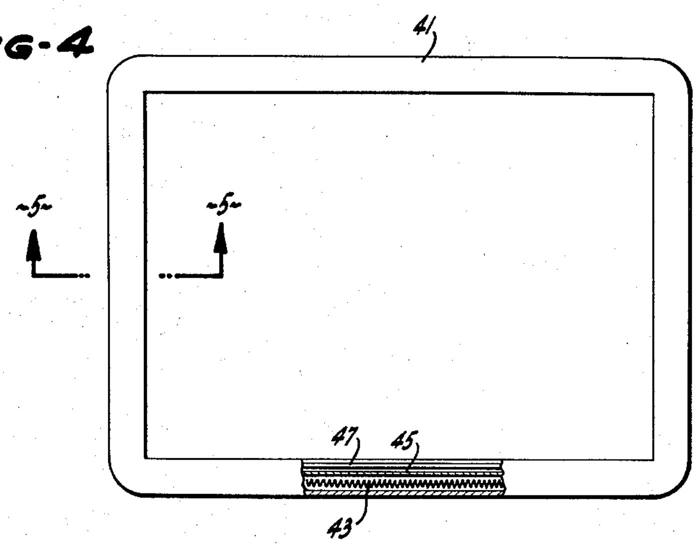


FIG-3

FIG-4



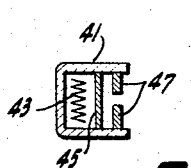


FIG-5

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STORAGE-TYPE COLOR DISPLAY TUBE

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3 Claims. (Cl. 315—12)

This invention relates to cathode-ray tubes of the storage type, adapted for the display of images in color for television, radar, and like purposes.

A "storage-type cathode-ray display tube," as the term is used herein, means a cathode-ray tube wherein the image traced by a scanning cathode-ray beam, instead of being displayed instantaneously, a point at a time, is effectively "stored" or retained for a greater or less period so that the path traced by the beam can be reproduced and displayed after the beam has passed. The period for which the image is retained can vary between wide limits; say, from 1/30 second, corresponding to the period of field repetition of television signals transmitted in accordance with present United States standards, or it can be for much longer periods, such as minutes, hours, or even days. Display of the image can be substantially concurrent with its production or "writing," the display of any individual area of the image field beginning at the instant that it is stored and continuing until that elementary area is again scanned by the electron beam, or the image may be held, invisibly, or "remembered" until it is reproduced at a later time.

Numerous storage-type monochrome display tubes have been suggested in the past; many of these are described in "Storage Tubes" by Knoll and Kazan (John Wiley and Sons, Inc., 1932), together with their general principles of operation and including the theoretical discussion of various ways of writing, reading and erasing the images produced and reference is made to this work for matters not discussed in detail herein. Obviously tubes of the storage type are considerably more complex than the simple type of cathode-ray display tubes as used in television receivers generally. Numerous types of cathode-ray tubes for the display of television or like images in color have also been proposed. These, too, have involved greater complexities than monochrome display tubes. Furthermore, in both storage tubes and color tubes the positioning of their various elements and the relative potentials at which these elements are operated are usually quite critical. Certain of these requirements of the two types of tubes have proved to be difficult to combine in a single device that would unite the purposes and advantages of both.

The broad purpose of the present invention is to provide a cathode-ray tube effectively combining the characteristics of storage and color type display tubes. More specifically, among the objects of the invention (not necessarily listed in the order of their importance) are the following:

(1) To provide a storage-type tube which will display a polychrome image with a definition substantially equal to that attainable by direct display;

(2) To provide a cathode-ray tube that will display images in color at greatly increased brilliancy as compared with that attainable with direct display;

(3) To provide a storage-type tube for displaying images in color which is capable of either displaying such images concurrently with their tracing or of retaining such images for a more or less indefinite period and later displaying them in color with substantially no degradation in resolution;

(4) To provide a tube adapted, without structural change, to use substantially any of the known techniques of writing, reading and erasure of the images, depending upon the particular use to which the tube is to be put; and

(5) To provide a tube which can readily be constructed in either two color or three color versions.

In order to describe the present invention in general terms it is simplest to consider first the known type of color television tube as proposed by one of the present inventors and described in his Patent No. 2,692,532. Such a tube comprises the usual evacuated envelope, preferably of generally funnel-like shape, having a viewing area or window in the large end of the funnel and an electron gun in the neck of the funnel and adapted to direct a narrow, collimated beam of electrons toward the center of the viewing area. Means for deflecting the beam bidirectionally to scan the viewing area may be incorporated within the tube in the form of deflecting plates, but are more usually provided by auxiliary coils encircling the neck to the tube when in use; the same is true of means for focusing the beam into its narrow pencil-like form. The display screen in such a tube is comprised of narrow strips of phosphors emissive of light of different colors upon electron impact, these strips extending across the full width of the viewing area in one dimension and each strip being less than one elemental area of the picture to be reproduced in width. Deposited over the layer of phosphor strips is a thin film of conducting material; preferably of aluminum or some other metal having a low atomic number, this film being so thin as to be electron-permeable.

Mounted between the electron gun and the screen, closely adjacent to and parallel to the latter, is a structure adapted to set up electric fields that will form a multiplicity of cylindrical electron lenses; i.e., electron lenses which tend to converge in one dimension, electrons entering the pupils thereof, leaving the component of the direction of their paths in the other dimension either unchanged or, sometimes, slightly divergent. This electron lens structure may take several forms, but it necessarily includes a color-control grid comprising two mutually insulated, interleaved sets of tightly stretched linear conductors, the conductors in each set being electrically connected. These conductors are so arranged that those of one set are electron-optically centered over phosphor strips emissive of one color upon the display screen while those of the second set are similarly centered over or alined with the centers of the strips emissive of a different color. By "electron optically centered" is meant that when normal operating potentials are applied to the various electrodes, those of both sets being at the same potential, the electron beam passing between any pair of adjacent conductors will converge to at least an approximate focus, midway between the centers of the two strips thus described. For a two-color tube the two strips may be contiguous; for a three-color tube, such as is normally employed in color television, strips of a third color will be interposed between the first two described. To control the color displayed different potentials are applied to the two sets of conductors of the color grid, thus deflecting the focal point toward one or the other of the strips of phosphor above which the grid conductors are centered.

In accordance with the present invention the electron lens system for accomplishing color control and focusing comprise first, a color control grid as above described, second, a screen grid, which may be either a mesh of fine wires or, preferably, a series of parallel wires extending transversely to those of the color control grid. Beyond these two grids, positioned in the plane that would normally be occupied by the display screen in a tube of the non-storage type, is a storage mesh comprising a foraminated sheet or netting of conductive material, coated, at least on the side facing the electron gun, with an insulating film having good secondary electron-emissive properties. The display screen itself is of the same type and conformation as would be used were it positioned in the plane of the storage mesh; it is spaced slightly beyond the storage mesh in a position as though moved back without rotation from the plane of the latter in a direction normal to its own plane.

Mounted between the screen grid and the storage mesh are first, a source of flood electrons, so directed as to form a space charge between the screen grid and the storage mesh, and second, closely adjacent to the storage mesh, a collector grid of fine wires. The preferred forms of the various elements described and the mode of the operation of the device will be explained in connection with a detailed description that follows, this description being illustrated by the accompanying drawings wherein:

Fig. 1 is a diagrammatic illustration of one embodiment of the invention, not to scale, the dimensions of the various elements being distorted in order to show more clearly the construction and disposition of the parts;

Fig. 2 is a diagram illustrative of the voltage gradients within the tube of Fig. 1;

Fig. 3 is a schematic diagram showing the connections of one form of flood electron source;

Fig. 4 is an elevation, partly in section, showing another type of flood electron source; and

Fig. 5 is a cross-sectional view of the source illustrated in Fig. 4, the plane of section being indicated by the lines 5—5 of the preceding figure.

The form of the present invention illustrated in Fig. 1 comprises the usual, generally funnel-shaped envelope **1**, which may be either of metal or glass; if of glass, it is provided with an inner conductive layer. The larger end of the envelope is closed by a glass window **3**; the small end terminates in a tubular neck **5**, also usually of glass, within which is mounted an electron gun. The latter comprises a cathode **7**, usually an intensity controlling grid **9**, and one or more anodes **11**, the last of which connects to the envelope or its conductive lining. Many forms of the electron gun are known, any of which may be used provided it is adapted to form a collimated narrow beam of electrons directed normally toward the viewing area. Connections from the various elements in the electron gun are made to pins **12**, carried by a base on the neck of the tube. In use, the usual focusing and deflecting coils surround the neck between the end of the anode **11**, and the start of the flare of the funnel.

The remaining elements within the envelope are all substantially planar in form and nearly equal in area and are mounted very closely adjacent to the viewing window **3**, in planes substantially normal to the undeflected path of the beam from the electron gun to the center of the window. The first of these elements is a color-control grid, comprising two mutually insulated interleaved sets of tautly-stretched, fine linear conductors $\mathbf{13}_1$ and $\mathbf{13}_2$, the conductors of each set being electrically connected together as shown schematically in the diagram. In a typical tube these conductors will be wires of about 4 mils diameter, spaced 10 to 20 mils on centers, depending on the total size of the tube and the area of its display screen.

The second element in the electron lens system is a screen grid **15**, formed of linear conductors similar to those forming the color-control grid but extending transversely to the latter across the tube. All of the screen grid conductors are connected together, however, and they need not be quite as closely spaced as the control grid conductors. If desired, a wire mesh may be used for the screen grid instead of the transverse conductors only, but the latter arrangement is preferred. The spacing between the color-control grid and the screen grid will typically be approximately about ½ inch.

Behind the screen grid again is a flood cathode **17**. In Fig. 1 this cathode is indicated symbolically as a resistor; actually it is formed as a grid or network of thermionically emissive wire, e.g., fine thoriated tungsten, connected as shown in Fig. 3. In Fig. 3 the emissive wires are those running laterally of the figure and indicated at $\mathbf{17}_1$. These are cross-connected to form a network through equalizers $\mathbf{17}_2$, the whole being supplied by leads **19**. As will be seen, the structure and method of connection is such as to put many short filaments in parallel connection so as to minimize the voltage difference between the various parts of the network and make its average potential as nearly uniform as possible, the total variation in voltage over the entire area of the cathode being only the order of 2 or 3 volts at most. Further, to minimize such voltage variations, the equalizers are made of low resistance conductor. The heating current for the elements is provided by a pair of batteries **21** and the bias source that establishes a mean operating potential of the cathode, in relation to the other elements of the tube, connects at a point **23** between the two batteries. In a typical tube, from which the dimensions of that herein described are taken, the spacing of the cathode from the screen grid is approximately 0.2 inch.

The next element of the tube, spaced, in the present case, 0.2 inch from the flood cathode **17**, is a collector grid **25**. This should be a mesh of very fine wire, 3 mils in diameter or less, the openings between the wires being relatively large in comparison with the wire diameter; e.g., 0.10 inch. Alternatively, it may be stretched parallel wires running unidirectionally, without the transverse members of the mesh.

A storage mesh **27**, upon which the operation of the tube primarily depends, is spaced 0.1 inch from the collector grid in a plane parallel thereto. This mesh is very fine. It may be woven wire, 250 or more meshes to the inch, or it may be a thin foraminated foil, formed, for example, by the etching process, with its foraminations spaced on centers by distances of the same order of magnitude as the woven mesh just mentioned. The storage element itself is deposited on the conductive base formed by the mesh or foil. It comprises an insulating layer which may, for example, be deposited on the conductive base by evaporation. Any of the numerous materials that have been suggested for the purpose may be used; these materials have in common that they have a relatively high secondary emission ratio and high insulation resistance. Among those that have been suggested and are, in fact, suitable, are the phosphors, such as the silicates, evaporated silica and aluminum oxide. This coating need only be deposited on the side of the mesh facing the electron gun.

The final element of the tube is a display screen, generally indicated by reference character **29**, mounted just within the viewing window 3 and approximately 0.25 inch from the storage mesh. It comprises a glass or other transparent base plate **31**, on which, facing the electron gun, is deposited a layer of phosphors 33 covered by a conducting film **35**. The phosphor layer comprises strips of phosphors emissive of different colors upon electron impact. These strips run substantially parallel to the wires of the color grids 13_1, 13_2. The number of different phosphors employed may be either two or three, preferably three if the device is to be used to reproduce color television signals, although in certain cases two color reproduction may be used for certain military, scientific, or other purposes. For a bi-color tube strips of one color, say red, are electron-optically centered behind conductors $\mathbf{13}_1$ of the color grid, while those of a second color, say, green, are similarly centered behind conductors 13_2. For a tri-color tube strips of the third color, say blue, are positioned midway between each pair of red and green strips. The order of the strips is, under the above assumptions, red, blue, green, blue, red, etc., there being twice the number of blue strips as of red or green. Which strip is chosen as the "center" strip is to a large degree arbitrary and depends on the particular system with which the tube is used. The order described is purely illustrative.

The strips are electron-optically centered beneath the color control grid conductors, not physically centered; except at the center of the screen a perpendicular dropped from the conductor 13_1 would not strike the center of the corresponding strip. What electron optically centered means, in the present instance, must be derived indirectly from the position such strips would occupy were the display screen moved to the position of the storage mesh 27. As will be described in more detail later, the electrons streaming from the gun emerge from it at a velocity corresponding to approximately 3 kilovolts, and are accelerated to 5 kv. at the screen grid, beyond which their velocities are substantially constant until they strike the storage mesh. The acceleration does not affect the paths of the electrons traveling down the tube axis. When deflected toward the edges of the screen in the scanning process, however, the accelerating forces are predominantly normal to the surfaces of the grids, the transverse components of the velocities being but little affected. Their trajectories can be computed, as has been described in the prior art, and the point at which an electron of the beam which would pass through the position occupied by one of the grid conductors 13_1 (were it not there) would strike the storage mesh is therefore "electron-optically centered" or alined behind that conductor.

The electrons used to excite the screen, however, are not those of the beam but those emitted from the flood cathodes 17. They are not subject to deflection but travel in paths perpendicular to the surfaces of the storage mesh and screen. The disposition of the strips on the screen is therefore what it would be were the screen moved axially of the tube without rotation about its axis, into the position of the storage mesh.

Separate connections are brought out of the tube for each of the sets of color-grid conductors, the screen grid, the flood cathode (as has already been described), the collector grid, the base conductor of the storage mesh and the conducting film 35 of the display screen. Some of these connections can be brought out through the pins 12 on the base; in other instances it is more convenient to bring them out through the walls of the tube. These connections are shown schematically, without necessarily indicating how they would be handled in any individual tube.

There are various ways of writing the signal on the storage mesh, all described in "Storage Tubes" by Knoll and Kazan, cited above. For purposes of the present description the operating parameters first described will be those suitable to "non-equilibrium writing" and "grid control reading" as described therein, it being understood that grid control reading will be utilized irrespective of the writing method actually employed. There are two sets of conditions that must be met which dictate the biases imposed upon the various electrode structures; first, the electron lens system established by the color-control grid 13 and the screen grid 15 must have a focal length of the proper magnitude to converge electrons passing between adjacent wires 13_1, 13_2 into a line focus, or approximate focus, giving a beam width not greater than one-half the width of one of the phosphor strips and preferably less. The focal length of the lens system here described depends upon the ratio between the initial accelerating voltage applied to the beam and the voltage between the color control grid and the screen grid. It

is but slightly affected by the presence of flood cathode 17 and collector grid 25. However, the voltage gradients within the space between the screen grid and storage mesh must be such as to permit proper writing or collection of stored charges without interfering with the reading of the signals as they appear on the display screen.

The voltage gradients used to accomplish these results are indicated by the plot of Fig. 2. It is convenient, for various reasons, to operate the conductive base of the storage mesh at ground potential. The plot of voltage gradients is based on the assumption that it is so operated but it is to be understood that under other circumstances any point of the system can be grounded, as long as the voltage differences between the various elements are in the proper ratio.

In the operation here illustrated the cathode 7 is biased at about 5 kv. negative to ground and the control grid 9 about 30 volts negative to the cathode. The final anode 11 of the electron gun is biased approximately 3 kv. negative to ground; in practice between about 2.7 and 3.3, it being this voltage that is varied to obtain the best focus of the beam by the color grid, both sets of conductors of the latter being operated at the same mean potential. The screen grid is grounded, so that there is approximately a 3 kv. difference in potential between it and the average potential of the color control grid conductors. In use, the color switching voltage may be applied to the color-control grid conductors through a transformer 37, the secondary whereof is provided with a center tap through which the bias potential is supplied.

With the voltage gradients and spacing of the parts as here described, the switching can be accomplished with an applied A.C. voltage across the color grid conductors of approximately 100 volts.

The flood cathode 17 is operated at a bias potential at about 10 volts positive and the collector grid about 150 volts positive to ground. The base potential of the storage mesh is, as before stated, zero. Except for the charges stored on the individual elements of the storage mesh, there is therefore no net potential difference between the screen grid 15 and the storage mesh 27. The maximum voltage difference within this space is therefore only in the neighborhood of 150 volts. This is so small in comparison with the 5000 electron-volt energy of the incoming electrons that it may be disregarded and the beam considered as though it were traveling in a field-free space; i.e., the effect of the flood cathode and the collector grid on the path of the high velocity beam is so small that it may be neglected.

With the materials used for coating the storage grid, the 5 kv. energy applied to the electron beam is substantially that required to operate it at the so-called "second cross-over point" of secondary electronic emission of the coating material (V_{cr2}, to use the notation generally employed); i.e., at the impact energy whereat the secondary electrons emitted from the surface are equal in number to the infalling primary electrons, provided all of the emitted electrons are collected by collector grid. Some of these are not so collected, however, due to space charge established between the collector grid and the storage mesh if the potential differences are those described, but under these circumstances, the charges collected on the various areas of storage mesh become proportional to the intensity of the impacting electron beam. This is controlled by the intensity control grid 9 of the electron gun. Under the circumstances here considered these charges are always positive. In scanning, therefore, the beam deposits, on the storage mesh, a charge pattern that corresponds in intensity to the light pattern that would be exhibited were the display screen moved to the same position.

The film 35 on the surface of the display screen is biased to a relatively high potential positive to ground; somewhere in the order of 10 kv., but this is not critical, The flood cathode 17 liberates electrons which, since the flood cathode is positive to both the screen grid and the base of the storage mesh, but negative to the collector grid, are attracted toward the latter, most of them passing through the meshes to form a substantially uniformly distributed space charge immediately adjacent to the secondary-emitting surface of the storage mesh and thus forming a virtual cathode between the storage mesh and the collector grid. This virtual cathode, the individual charges on the storage mesh, and the conductive film on the display screen therefore form, in effect, a triode, with the stored charges acting as control signals on the grid to control the electron flow.

The graph of Fig. 2 illustrates, only very roughly to scale, potential gradients within the tube, the dotted lines indicating the approximate positions along the axis of the tube whereat the various bias voltages are applied. The difference between the cathode voltage E_0 and the bias E_i at the intensity-control grid is too small to show on the scale selected. The potential of the anode 11 is substantially equal to the bias voltage E_1 applied to the color control grid, so that through the major portion of the tube the beam travels through a substantially field-free space. A steep potential gradient accelerates the beam between E_1, the color-control grid potential and E_2, the screen-grid potential at ground. The storage mesh is also biased to the same potential E'_2, but between these elements a very small potential gradient exists between the screen grid and the collector grid biased at E_c. This gradient is shown on a somewhat exaggerated scale, but even at this scale, the 10 volt rise from E_2 to E_f is too small to show. Beyond the storage mesh is the steep gradient rising to 10 kv. at E_3.

Because of the extended parallel surfaces of the storage mesh and the display screen, the lines of force between the two are normal to both and the paths of electrons penetrating the mesh of the storage screen follow the lines of force, so that the image displayed upon the display screen is substantially identical with that which would be shown upon direct scanning. It should be mentioned that the display screen may be formed directly on the window 3. The window is almost always slightly curved to enable it better to withstand the air pressure on its surface. If the curvature is slight it will have little effect on the electron trajectories between the storage mesh and the screen, as the lines of force are nearly normal to the storage mesh until the electrons have reached nearly their terminal velocity. If the screen is more deeply curved the trajectories can be computed and allowance made in positioning the phosphor strips.

The pattern displayed may, however, be very much brighter than that of a directly scaned display screen, depending upon the way in which the tube is used. Any of the various known methods of erasing an image that has been written upon the storage mesh in one scanning, preparatory to the re-storage of a new image, may be used. These have been described in the text above referred to.

One method, involving a different mode of writing, is of particular interest; i.e., equilibrium writing.

In this method of writing the cathode 7 is operated at a potential negative to the storage mesh somewhat greater than V_{cr2}, and an unmodulated beam of high intensity is employed, the grid 9 being coupled back to the cathode 7 through a condenser in order to insure that no material A.C. potentials appear between them to cause variation of beam intensity, while still permitting the proper difference in bias potential between the two. The collector grid is operated at about the same or at a slightly lower potential difference with respect to the grounded base of the storage mesh as in the case previously described.

Under these circumstances the elementary areas of the storage mesh that are under bombardment from the scanning beam will tend to assume an equilibrium potential such that the secondary electrons to the collector grid are equal in number to the primary electrons from the beam. This equilibrium potential is a constant for a given structure and cathode potential. The quantity of the charge required to bring any element of the storage surface to equilibrium depends upon the potential difference between the collector grid and the conducting base of the storage mesh, still assuming constant cathode potential; it will vary with the latter.

The signal voltage can therefore be applied either to the cathode, the collector grid, or the storage mesh, there-being some slight advantage in applying it to the cathode as this does not affect the triode operation of the flood cathode-storage-mesh-display screen combination. Any one of the three will work, however, provided the signal is applied in the proper polarity.

If cathode modulation is used a positive signal will decrease the impact velocity of the beam, and since operation is beyond the cross-over voltage V_{cr2}, will increase the secondary emission, and thus tend to drive the impacted area positive, increasing the brightness of the corresponding area of the screen.

Applying the signal to the collector grid, the charged surface tends to assume the same potential as the grid and in this case also a positive signal corresponds to a positive charge and increased brightness of the corresponding point on the screen.

Applying the signal to the storage mesh the reverse is the case; with a positive signal the charge collected on the storage surface must be negative to restore equilibrium, resulting in fewer electrons passing the mesh in the triode operation of the device. The signal polarity must therefore be reversed as compared with a grid-modulated direct display tube or the other two methods of operation.

In this last-described mode of operation, the flood-electron flow will vary constantly with the variation in storage-mesh voltage. Over the period of a frame, however, the electron flow will correspond to the average voltage of the mesh, varying above and below the zero axis of the A.C. component of the signal. This method of applying the signal is therefore operative, although less elegant than the others.

With all three modes of equilibrium writing the storage-mesh elements are recharged (or discharged) to their new equilibrium potentials each time they are scanned by the beam, thus erasing their former charges. The image on the screen is therefore displayed without interruption, giving a picture without flicker or "color crawl."

In equilibrium writing one of the principle concerns is to obtain a sufficiently intense beam to obtain complete equilibrium. High current beams tend to diverge, because of the coulomb effect. In the present device the electrons passing between any pair of color grid wires are re-focused to an area much smaller than the initial cross-section of the beam. Therefore higher densities and better approach to equilibrium can be attained than with most devices using equilibrium writing.

Another method of introducing the flood electrons into the space between the screen grid and the collector grid is illustrated in Figs. 4 and 5. In this arrangement the source of the flood electrons surrounds, at least partially, the area into which the electrons are introduced. The electron source is a "gun" comprising a glass frame 41 of U- or channel-shaped cross-section, with the open end of the U directed inward; this member or frame may either be mounted within the envelope or sealed in its walls substantially in the plane of the cathode 17 of Fig. 1. Within the U section of the frame, starting at the bottom of the channel, is a heater element 43, an electron emissive cathode 45 and an anode 47, slotted to permit egress of the electrons from the cathode.

In operation the anode 47 is biased a few volts positive to ground potential, the cathode slightly less positive, the actual values of the biases being determined by experiment at the best values to give a uniform distribution to the injected electrons.

This arrangement has considerable flexibility in operation. The cathode can be sectionalized so that the various sections can be operated at different biases to secure the best and most uniform distribution of electrons within the region between the screen grid and the grid. In some instances it is possible to omit entirely the cathode sections on the shorter sides of the rectangular frame, provided a rectangular tube is used. With the cathode operated at a potential slightly positive to the bias potential of the storage mesh, and accelerated toward the latter by the collector grid, electrons will approach the storage mesh as a result of their acceleration but not strike it as long as no part of its surface reaches a potential that is as far positive as that of the cathode. As a result, if the supply of electrons from the flood cathode is adequate, the desired virtual cathode will form immediately in front of the storage mesh but will penetrate the latter only to the extent that the field from the display screen penetrates it, the effective penetration, of course, being modified by the charges collected by the storage plate.

It will be appreciated that the electron flow through the storage mesh need not be large in order to produce a display that is very brilliant in comparison with the one produced by a scanning electron beam. In the ordinary television display tube the current carried by the electron beam is only a fraction of a milliampere. At the rate of scanning dictated by present U.S. standards of transmission the beam falls upon any individual area for only about $\frac{1}{400,000}$ of the total time during which the picture is displayed. For intervals of the order of magnitude of the frame frequency the eye integrates the light it receives from a given area. The light emitted from the display screen is, to at least a first approximation, proportional to the energy input to the screen. It will thus be seen that even if the display screen is operated at a voltage of only one-half that utilized between the cathode and screen of a tube using direct scanning, individual areas of the storage mesh need pass only about $\frac{1}{200,000}$ of the current in the scanning beam to produce equal brightness. The actual current density may be a great deal higher than this, giving a high degree of brilliancy. Some electrons of the scanning beam will, of course, penetrate the storage mesh and strike the screen but these are so small in number in comparison with the electrons from the flood gun or cathode that their effect on the display is negligible.

If the equilibrium method of writing and erasure are employed, television images can be produced without flickers; because the mesh is always negative to the flood cathode it collects no electrons from the latter and the image fades or deteriorates only as a result of the leakage through the insulating, secondary-emissive material. Since the effective resistance of the material is very high and the voltage differential between the charges collected upon it and its biasing potential are small, the rate of leakage can be very low and the stored image maintained for long periods. This is advantageous in many applications of the device where a record is to be produced for later viewing. It is also possible to use alternate writing and reading and erasure in the same manner as has been proposed for monochrome storage display tubes. Since the techniques for this type of operation are well-known it appears unnecessary to describe them in detail here.

While specific voltages, electrode spacings, grid wire dimensions and phosphor strip widths have been given in this description, this has been done for illustrative purposes only. Different secondary-emissive materials have different cross-over points and since in most methods of operation the potential difference between the cathode of the electron gun and the conductive base of the storage-mesh should be substantially equal to the cross-over point voltage, different voltages may be required for different secondary emissive materials. In this case the bias voltages applied to other elements within the tube will have to be changed. The focal length of an electron lens depends upon the ratio of the voltages applied to its various elements and not upon their absolute values. Thus, if the second cross-over voltage of a particular material used for the insulating coating of the storage mesh were found to be, say, 3000 volts instead of 5000, the only change required to produce the results here described would be a scaling down of the voltages, E_0 and E_1 to $\frac{3}{5}$ of the values given; i.e., to 3 kv. for E_0 and 1.8 kv. instead of 3 as the normal value of E_1.

The spacings between the color grid, screen grid, and storage mesh may be changed if suitable changes are made in the relative potentials applied to them. A steeper potential gradient between color grid and screen grid will shorten the effective focal length of the electron lenses and permit closer spacings. Lower beam velocities between the electron gun and the color grid will permit lower switching voltages. All of these relationships are now well-known and electron lens systems can be devised in accordance with known principles to meet specific requirements. The only intended limitations upon the scope of inventions are therefore those that are expressed in the claims that follow.

What is claimed is:

1. In a storage-type cathode-ray tube for the display of images in color, the combination, within an evacuated envelop including a viewing area at one end thereof and an electron gun at the opposite end thereof adapted to develop a concentrated beam of cathode rays directed toward said viewing area, of elements designated as elements (*a*) to (*g*), mounted in succession between said electron gun and said viewing area and defined as follows:

Element (*a*): a color-control grid of substantially equal dimensions to said viewing area comprising two interleaved and mutually insulated sets of parallel linear conductors, the conductors of each set being interconnected and the spacing between adjacent conductors of the respective sets being of the order of magnitude of an elementary area of the image to be displayed;

Element (*b*): a screen grid mounted parallel and adjacent to element (*a*) and comprising parallel conductors extending in a direction transverse to the conductors of element (*a*);

Element (*c*): a source of flood electrons for establishing a space charge behind element (*b*) as viewed from element (*a*);

Element (*d*): a collector grid mounted in a plane parallel to elements (*a*) and (*b*) and of substantially like dimensions thereto;

Element (*e*): a charge-storage mesh mounted parallel to element (*d*) and comprising a foraminated base of conductive material having a coating of insulating secondary-emissive material adherent thereto on at least the side thereof facing element (*d*);

Element (*f*): a display screen mounted parallel to element (*e*) and comprising a light transmissive base, a layer of phosphors thereon comprising parallel strips of phosphors emissive on electron impact of light of different colors, strips of one color being alined electron optically behind the conductors of one of the sets of element (*a*) and strips emissive of a different color being so aligned behind the conductors of the other set thereof, and an electron-permeable conductive layer overlying said phosphor layer; and

Element (*g*): leads for applying different electrical potentials respectively to the two sets of conductors of element (a), to elements (b), (c), (d), (e), and the conductive layer of element (f).

2. The combination as defined in claim 1 including, in addition, means for varying the intensity of said electron beam.

3. In a storage-type cathode-ray tube for the display of images in color, the combination, within an evacuated envelope including a viewing area at one end thereof and an electron gun at the opposite end thereof adapted to develop a concentrated beam of cathode rays directed toward said viewing area, of elements designated as elements (a) to (g), mounted in succession between said electron gun and said viewing area and defined as follows:

Element (a): a color-control grid of substantially equal dimensions to said viewing area comprising two interleaved and mutually insulated sets of parallel linear conductors, the conductors of each set being interconnected and the spacing between adjacent conductors of the respective sets being of the order of magnitude of an elementary area of the image to be displayed;

Element (b): a screen grid mounted parallel and adjacent to element (a) and comprising parallel conductors extending in a direction transverse to the conductors of element (a);

Element (c): a cathode comprising a grid of thermoemissive filaments, said cathode having over-all dimensions substantially similar to elements (a) and (b) and being mounted in a plane parallel thereto;

Element (d): a collector grid mounted in a plane parallel to elements (a) and (b) and of substantially like dimensions thereto;

Element (e): a charge-storage mesh mounted parallel to element (d) and comprising a foraminated base of conductive material having a coating of insulating secondary-emissive material adherent thereto on at least the side thereof facing element (d);

Element (f): a display screen mounted parallel to element (e) and comprising a light transmissive base, a layer of phosphors thereon comprising parallel strips of phosphors emissive on electron impact of light of different colors, strips of one color being alined electron optically behind the conductors of one of the sets of element (a) and strips emissive of a different color being so alined behind the conductors of the other set thereof, and an electron-permeable conductive layer overlying said phosphor layer; and

Element (g): leads for applying different electrical potentials respectively to the two sets of conductors of element (a), to elements (b), (c), (d), (e), and the conductive layer of element (f).

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